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(73) Proprietor: **AT & T Corp.**
32 Avenue of the Americas
New York, NY 10013-2412 (US)

(72) Inventor: **Gaebe, Carl E.**
110 Deysher Road
Fleetwood, Pennsylvania 19522 (US)
Inventor: **Yeh, Xian-Li**
1293 Butternut Lane
Macungie, Pennsylvania 18062 (US)

(74) Representative: **Watts, Christopher Malcolm Kelway, Dr. et al**
AT&T (UK) LTD.
AT&T Intellectual Property Division
5 Mornington Road
Woodford Green Essex IG8 OTU (GB)

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Jouve, 18, rue Saint-Denis, 75001 PARIS

Description

Background of the Invention

Technical Field

The present invention relates to a silicon-based optical subassembly and, more particularly, to an optical subassembly including a silicon substrate with a plurality of etched openings for positioning of various optical components.

Description of the Prior Art

Semiconductor optical devices such as lasers are used in a wide variety of applications, due to their compactness, relatively high efficiency, and well-controlled output. However, a number of requirements are imposed upon these devices. For durability, cooling of the optical device is often necessary, since prolonged high temperature operation can seriously damage and even destroy the device. Further, since the output light intensity from the device is a function of its junction temperature, the supporting structure must be able to efficiently dissipate the heat generated by the high current density in the device in its operating state.

Issues regarding the assembly of these semiconductor optical devices with the required lensing and other passive optical components is another area of concern. In most conventional optical subassemblies, the supporting structure may comprise a number of different members. For example, a conventional optical subassembly may utilize one member for the active (e.g., laser) device and a separate member for the passive components. Alignment between the two members is thus required to achieve the desired minimum level of acceptable coupling loss. Alternatively, a single mounting member may be used to hold all the required optical components. In the latter arrangement, each mounting member is individually formed, using precision die-cast piece parts, for example. Additionally, active alignment operations are often required as each component is affixed to the mounting member. As a result, the optical subassembly is often a relatively expensive component of a lightwave transmitter, requiring a relatively long, expensive and tedious assembly process. Further, any modifications in the size, number or arrangement of the optical components often necessitates a redesign of the complete optical subassembly.

Thus, a need remains in the prior art for an optical subassembly which is robust in design, relatively simple to assemble (i.e., requiring few, if any, active alignments), and more amenable to high-volume, low-cost manufacture than those available in the prior art. Further, a need remains for an optical subassembly, including an isolator, which is capable of efficiently controlling the temperature of both the laser and the isolator.

Summary of the Invention

The needs remaining in the prior art are addressed by the present invention which relates to an optical subassembly and, more particularly, to a silicon-based subassembly including a plurality of etched openings for positioning of various optical components according to claims 1 and 20.

In accordance with the teachings of the present invention, a silicon substrate is processed to form a plurality of openings for placement of the required optical components. In one particular embodiment, the silicon substrate is etched to include a fist opening for placement of a first (e.g., subassembly-to-fiber coupling) lens, a second opening for placement of isolator optics, and a third opening for placement of a second (e.g., laser-to-isolator coupling) lens. A fourth opening for placement of a laser diode chip carrier may also be included.

During the actual fabrication process, a silicon wafer may be patterned and etched to simultaneously form hundreds of subassemblies. In an alternative embodiment, the second opening (for the isolator) may be eliminated - this design is especially suited for low speed applications where isolation of the laser from the remaining components is not necessary. Alternatively, this second opening may be used to hold other passive optical components, such as a third lens or filter.

It is an advantage of the present invention that the isolator optics are included on the same substrate as the laser such that both components are cooled by the same thermoelectric cooler (TEC) so as to operate at the same (controlled) temperature. Additionally, the isolator's magnet is thermally separated from the remaining elements forming the optical subassembly. As mentioned above, the cooling of the magnet in prior art designs is not necessary and only serves to increase the cooling load on the TEC. Thermal separation is achieved in accordance with one aspect of the present invention by supporting the silicon substrate in the cantilever arrangement so as to pass through the open core region of the isolator's magnet in a manner such that physical contact between the magnet and substrate is avoided. A support member, attached to the underside of the substrate in the vicinity of the laser, is used to form the cantilever arrangement with the substrate and prevent physical contact between the silicon substrate and the magnet. In one embodiment, the support member is the thermoelectric cooler (TEC) which is advantageously attached to the underside of the silicon substrate in the vicinity of the laser diode and isolator optical component. The use of silicon as the submount material provides for relatively quick transport of temperature

changes from the TEC through the substrate to the laser and isolator optics.

Another advantage of the present invention is that the etching process used to form the openings is relatively simple and may be controlled so as to provide the required optical alignment between the various components placed in the openings without the need to perform timely (and costly) active alignments subsequent to assembly.

A further advantage is that the submount (the silicon substrate) may be redesigned merely by changing the masks used to delineate the locations of the various openings.

Various and other advantages of the present invention will become apparent during the course of the following discussion and by reference to the accompanying drawings.

Brief Description of the Drawing

Referring to the drawings, where like numerals represent like parts in several views:

FIG. 1 is a view in perspective of a silicon-based submount formed in accordance with the present invention;

FIG. 2 contains a view in perspective of the submount of FIG. 1, with the various optical components attached thereto so as to form an exemplary silicon-based optical subassembly;

FIG. 3 is a top view of the arrangement of FIG. 2, illustrating in particular the disposition of the optical isolator with respect to the lens components;

FIG. 4 is a side view of the arrangement of FIG. 2, illustrating the depths of the openings created in the silicon submount for the various optical components;

FIGs. 5-8 illustrate an exemplary processing sequence used to form a silicon submount of the present invention; and

FIG. 9 illustrates an alternative silicon-based optical subassembly formed in accordance with the present invention, including high frequency interconnections to an external signal source.

Detailed Description

Throughout the course of the following discussion, the silicon substrate used to hold the various optical components will be referred to as the "submount"; the arrangement including the submount and the various optical components attached thereto will be referred to as the "optical subassembly", or simply, the "subassembly".

FIG. 1 contains a view in perspective of an exemplary silicon-based optical submount 10 formed in accordance with the present invention. In this particular arrangement, submount 10 comprises a silicon substrate 11 which is processed to include a plurality of openings, formed in top surface 13 thereof, for the placement of a plurality of optical devices. In the exemplary embodiment of FIG. 1, silicon substrate 11 is formed to include a first opening 12 for placement of a first lens. As shown, opening 12 is formed as a rectangular trapezoid, with sidewalls 14,16 which slant inwardly towards a bottom surface 18. Opening 12 is so formed with predetermined dimensions appropriate for placement therein of a cylindrically-shaped graded-index (GRIN) lens (FIG. 2), used to focus the collimated optical signal entering the lens into an external optical communication medium, for example, the core region of an attached optical fiber (FIG. 2). It is to be noted that a square- or spherically-shaped lens would require a different sized opening.

A second opening 20, relatively small and square in form, and also including inwardly tapering sidewalls, is formed in top surface 13 of silicon substrate 11 along the illustrated z-axis in tandem with first opening 12. Opening 20 may be used to hold a second lens, for example, a spherical lens which is used to collimate the optical signal exiting an active optical device (e.g., laser). Second opening 20 is formed to comprise suitable dimensions such that the input beam from the active device will intercept a spherical lens in a manner such that the lens will form a collimated output signal.

A third opening 22 is formed between first opening 12 and second opening 20, along the z-axis of substrate 11 as shown in FIG. 1. Third opening 22 also comprises a rectangular trapezoidal shape, with side faces 24, 26 sloping inwardly towards a bottom surface 28. Opening 22 may be used, as shown in later figures, to hold the optical component portion of an optical isolator. As mentioned above, an optical isolator may be used in high bit rate applications where it is desired to prevent any significant reflections from re-entering the laser active region. In this particular embodiment, the physical dimensions of the isolator are somewhat smaller than those of the GRIN lens. Therefore, opening 22 is somewhat smaller than opening 12. As will be discussed in detail below, the relative sizes of the openings may differ, as dictated by the dimensions of the various components contained therein. A fourth, relatively shallow opening 22 may be located behind opening 20. Opening 30 is utilized for placement of the chip carrier holding the active optical device. In an alternative embodiment, the chip carrier may be attached directly to top surface 13 of substrate 11.

FIG. 2 contains a view in perspective of an optical subassembly 32 utilizing the silicon-based submount 10 of FIG. 1. In a typical packaging sequence, a GRIN lens 34 and spherical lens 36 are placed in and attached to openings 12 and 20, respectively, using, for example, a glass solder. Advantageously, the tapered sidewalls of openings 12,20 provide for physical contact for the edges thereof. to silicon substrate 11. A

chip carrier 38, holding a pre-bonded laser 40, is next aligned with and soldered to a metal contact deposited in opening 30 (or alternatively, mounted directly on substrate top surface 13). As will be described below, the process of etching the various openings may be sufficiently controlled so as to provide, for example, a ±5 μm alignment tolerance between laser 40 and lens 36. Subsequent to the placement of chip carrier 38, the optical component portion 42 of an isolator 44 is attached to opening 22. A backface monitor 46 may be placed as shown in FIG. 2 so as to intercept the light emitted from the rear face of laser 40. The output from backface monitor 46 is coupled to an external monitoring circuit (not shown) which functions to adjust the laser to maintain constant output power by, for example, controlling the laser bias current. A temperature sensor 47 is located in close proximity to laser 40 and optical component 42 so as to monitor the ambient temperature of the packaged arrangement in the vicinity of laser 40 and component 42. The output from sensor 47 is coupled to a thermoelectric cooler (TEC) 48 which functions to regulate the operating temperature of laser 40 and isolator optics component 42, in response to the signal from sensor 47, such that a relatively constant laser/isolator optics temperature is maintained.

As discussed above, an advantage of the arrangement of the present invention is that TEC 48 may be attached to the underside of silicon substrate 11, in proximity to both laser 40 and isolator optics 42. The choice of silicon as the submount material is particularly suited for this aspect, since silicon is known to exhibit excellent thermal transport properties such that any change in the temperature of TEC 48 will be quickly transferred through substrate 11 to laser 40 and isolator optics 42. Alternatively, if the subassembly does not utilize a TEC in this position, a support block 50, for example, another silicon substrate, may be attached to the underside of the optical subassembly in proximity to laser 40.

TEC 48 (or support block 50) is used as shown in FIG. 2 to provide a cantilever arrangement. In particular, the far end 51 of substrate 11 is cantilevered with respect to support block 50. The cantilever design is advantageous in the optical subassembly of the present invention, since the design allows for the permanent magnet portion 52 (shown in phantom) of isolator 44 to be slid over the subassembly and positioned to surround isolator optics 42 without touching silicon substrate 11. Since the two pieces are not in physical contact, any temperature changes of silicon substrate 11 as a result of the operation of TEC 48 (or any other TEC attached to substrate 11) will not be transferred to magnet 52. The thermal isolation between TEC 48 and magnet 52 thus prevents any unnecessary cooling of magnet 52.

FIG. 3 illustrates a top view of optical subassembly 32, showing in particular the positioning of isolator optics 42, permanent magnet 52, and the path of the central ray through the system. The angling of optics 42 relative to opening 20 is evident in this view. In particular, isolator optics 42 may be tilted at a predetermined angle (6°, for example) with respect to the central ray and opening 22. The purpose of the tilt is to achieve improved isolation and is not germane to the present discussion regarding the optical subassembly. Additionally, as shown in FIG. 3, a connecting fiber 54 may contain a beveled endface 55 (formed at an angle of 6°, for example) to further reduce reflections.

A cut-away side view of optical subassembly 32 is illustrated in FIG. 4. In this view, the path between the optical components is clearly illustrated, along with the signal path between laser 40 and backface monitor 46. The positioning of each component within its associated opening is clearly visible in this particular view. The alignment of backface monitor 46 with laser 40 is obvious from this view Further, as shown, it is not necessary that each component rest in the base of each opening, since the physical contact between the component and the opening is in reality provided along the sidewalls of the opening. In FIG. 4, GRIN lens 34 is particularly illustrated as being disposed above bottom surface 18 of opening 12. Therefore, the fabrication process of submount 10 is considered to be somewhat tolerant to fluctuations related to the depths of the various etch processes.

The following discussion is descriptive of an exemplary process for fabricating silicon submount 10 to include the required openings for placement of the various optical components. It is to be understood that although the discussion and associated figures are related to the formation of a single silicon submount, hundreds of such submounts may be formed simultaneously when a silicon wafer is subjected to the fabrication process. Further, the following process steps and/or their sequence are not considered to be unique; various modifications may be utilized to provide a silicon-based submount within the scope of the present invention.

In one exemplary processing sequence, a <100> silicon substrate 11 is provided, where the <100> orientation is utilized so that subsequent etching of top surface 13 will create openings with tapered sidewalls, since the sidewall <111> orientation is known to etch at a relatively slow rate with respect to the etch rate of <100> silicon (ratio of approximately 1:25). As shown in FIG. 5, a relatively thick (for example, approximately 5000 Å) oxide layer 60 is first grown on the top surface 13 of substrate 11. Oxide layer 60 is then patterned (using well-known exposure techniques) to delineate the locations of openings 12, 20 and 28. The exposed oxide is then etched in these areas so as to leave a relatively thin (for example, approximately 1000 Å) oxide layer over surface 13 of substrate 11 at the locations of openings 12, 20 and 22. FIG. 6 illustrates the substrate with an etched ox-

ide layer 60. Metallization 64 required for eventual electrical connection of chip carrier 38, backface monitor 46, and temperature sensor 47 is then deposited over oxide 60 in the appropriate locations, as illustrated in FIG. 6. A second metal layer 66 may then be sputtered on the backside of substrate 11, where metal layer 66 serves as signal ground for the completed subassembly.

After the metallization process, oxide layer 60 is patterned and etched to expose surface 13 of substrate 11 at the locations for openings 12 and 28. A buffered oxide etch may be used for this purpose. The exposed silicon surface 13 is then etched for a predetermined period of time to provide an opening sufficient for placement of lens 36, as illustrated in FIG. 7. In particular, a depth d_2 may be in the range of 100-200 μm. As mentioned above, all depths are meant to be exemplary only, since each design will require various modifications as a function of the dimensions of the optical components.

Opening 20 for isolator optics 42 is next formed by first removing oxide layer 60 above silicon surface 13 in the predetermined areas for optics 42. Substrate 11 is then masked to expose only the location of openings 12 and 20. The exposed locations are then etched for a predetermined period of time sufficient to create opening 20 with a depth d_3 appropriate for isolator optics 42. In particular, this depth may be in the range of 400-500 μm. As shown in FIG. 8, the second etch in the location of opening 12 results in a depth d_1 of approximately $d_2 + d_3$, sufficient for placement of a GRIN lens 34, where d_1 may be in the range of 500-700 μm. It is to be noted that depending upon the required sizes, openings 12, 20 and 22 may be created in three separate pattern and etch routines. Additionally, as mentioned above, a fourth opening 30 may be formed behind opening 20 for the placement of chip carrier 38. Opening 30 is relatively shallow, on the order of 10-20 μm. FIG. 8 illustrates a processed submount including opening 30.

FIG. 9 illustrates an alternative silicon-based optical subassembly 68 formed in accordance with the present invention. In this embodiment, referred to as a coplanar connection subassembly, the signal ground plane is provided, using vias through the substrate, on top surface 13 of substrate 11. In particular, the high frequency signal connections to laser 40 are provided by a first connection 70 and a second connection 72. Connection 70 is attached to a first metallic strip 74, where strip 74 is subsequently attached to chip carrier 38. Second connection 72 is coupled by a series of vias (not shown) to a second metallic strip 76 disposed on the underside of substrate 11 (illustrated in phantom in FIG. 9). First metallic strip 74, silicon substrate 11 and second metallic strip 76 form a stripline to provide a high frequency interconnection between an external signal source (not shown) and laser 40. A thin film resistor 78 is located on chip carrier 38 in proximity to laser 40 to provide impedance matching of the laser to the stripline. A thorough description of an exemplary silicon-based high-frequency interconnection may be found in Serial No. 287,778, fled December 21, 1988, entitled "Silicon-Based Mounting Structure for Semiconductor Optical Devices", and assigned to the assignee of the present invention. As disclosed therein, a silicon substrate is processed to include a via in proximity to the laser so as to provide for attachment of the underlying metallic strip to the top-side laser contact. The use of such a via connection, in conjunction with the impedance matching resistor, provides for a relatively robust high frequency connection at data rates exceeding 2 Gb/s.

It is to be noted that there exist various modifications to the silicon-based optical subassembly which are considered to fall within the scope of the present invention. For example, various optical filters, such as wavelength-selective filters or dichroic filters may be placed in silicon submount openings and optically aligned with the associated active device(s). Further, a single submount could be formed to include an array structure of active devices, with the necessary passive components appropriately disposed in the silicon submount. Alternatively, an optical subassembly of the present invention could be configured as a optical transceiver subassembly including an optical transmitting device, an optical receiving device and the required lensing and filtering components.

Claims

1. An optical subassembly comprising:

   a plurality of optical devices (34,36,40,44);

   a silicon substrate (11) defined as including a major top surface (13), said silicon substrate including a plurality of openings (12,20,22,30) formed in the top surface thereof, the plurality of openings for placement of said plurality of optical devices and disposed so as to provide optical alignment therebetween; and

   a support member (e.g., 48,50) disposed with respect to said silicon substrate so as to form a cantilever arrangement therewith.

2. An optical subassembly as defined in claim 1 further including at least one active optical device (40).

3. An optical subassembly as defined in claim 2 wherein the at least one active optical device comprises a laser.

4. An optical subassembly as defined in claim 2 wherein the at least one active optical device is placed within an opening (30) in the silicon substrate top surface in proximity to the support

member.

5. An optical subassembly as defined in claim 2 wherein the plurality of optical devices further includes an optical isolator (44).

6. An optical subassembly as defined in claim 5 wherein the optical isolator comprises

an isolator optical component placed within an opening in the silicon substrate top surface so as to be in optical alignment with the active optical device; and

a permanent magnet (52) disposed to surround the isolator optical component in a manner such that physical contact with the silicon substrate is avoided.

7. An optical subassembly as defined in claim 2 wherein the plurality of optical devices further includes at least one passive optical component (34,36).

8. An optical subassembly as defined in claim 7 wherein the at least one passive optical component comprises

a first lens (34) for coupling an optical signal exiting the optical subassembly to an external optical communication medium; and

a second lens (36) coupled to the active optical device for collimating the optical output therefrom.

9. An optical subassembly as defined in claim 8 wherein the external optical communication medium comprises an optical fiber (54).

10. An optical subassembly as defined in claim 8 wherein

the first lens comprises a graded index lens of cylindrical shape for transforming a collimated input beam into a focused output beam; and

the second lens comprises a spherical lens for collimating the optical input signal applied thereto.

11. An optical subassembly as defined in claim 10 wherein the silicon substrate includes

a first opening (18) for the first lens, said second opening comprising a relatively trapezoidal shape of a depth d_1; and

a second opening (20) for the second lens, said second opening comprising a relatively square pyramidal shape of a depth d_2.

12. An optical subassembly as defined in claim 11 wherein depth d_1 is within the range of approximately 500-700 μm, and depth d_2 is within the range of approximately 100-200 μm.

13. An optical subassembly as defined in claim 2 wherein the support member comprises a thermoelectric cooler.

14. An optical subassembly as defined in claim 13 wherein the thermoelectric cooler is disposed with respect to the silicon substrate so as to provide a thermal transport path through said silicon substrate to the active optical device.

15. An optical subassembly as defined in claim 14 wherein the plurality of optical devices further comprises an optical isolator including an isolator optical component placed within an opening in the silicon substrate top surface and disposed along the thermal transport path from the thermoelectric cooler and said silicon substrate.

16. An optical subassembly as defined in claim 2 wherein the at least one active optical device is disposed on an optical chip carrier (38), said optical chip carrier being attached to the top surface of said silicon substrate.

17. An optical subassembly as defined in claim 16 wherein the chip carrier is attached within an opening formed within the top surface of the silicon substrate, the depth of the opening such that active region of optical device remains disposed above the top surface of said silicon substrate.

18. An optical subassembly as defined in claim 2 wherein the at least one active device further comprises as a second active device a backface monitor (46) positioned to intercept the optical signal exiting the rear face of the first active device.

19. An optical subassembly as defined in claim 1 wherein the silicon substrate comprises <100> oriented silicon such that the plurality of openings include inwardly tapering sidewalls of <111> orientation.

20. An optical subassembly comprising

an active semiconductor optical device (e.g., 40);

isolating means (e.g., 44) for preventing reflected signals from reentering said active semiconductor optical device;

a second lens (e.g., 34) disposed after said isolating means for focusing the output from said isolating means into a coupled optical waveguiding medium;

a second lens (e.g., 36) disposed between said active device and said isolating means for

collimating the output from said active device into the input of said isolating means; and

a silicon substrate (e.g., 11) including a plurality of openings (e.g., 12,20,22,30) formed in the top surface thereof for placement of said isolating means and said first and second lenses, the plurality of openings disposed so as to provide optical alignment therebetween.

21. An optical subassembly as defined in claim 20 wherein the isolating means comprises

an isolator optical component (42) placed in an opening in the silicon substrate; and

a permanent magnet (52) disposed to surround said silicon substrate in the vicinity of said isolator optical components;

the subassembly further comprising

support means (48) attached to the underside of the silicon substrate in a manner to provide a cantilever optical subassembly arrangement wherein physical contact between said permanent magnet and said silicon substrate is avoided.

22. An optical subassembly as defined in claim 21 wherein the support means comprises a thermoelectric cooler attached to the underside of the silicon substrate in the vicinity of the active semiconductor optical device and the isolator optical component.

23. An optical subassembly as defined in claim 20 wherein

the first lens comprises a cylindrical GRIN lens (34), placed in a relatively rectangular pyramidal opening in said silicon substrate; and

the second lens comprises a spherical lens (36), placed in a relatively square pyramidal opening in the silicon substrate.

24. An optical subassembly as defined in claim 20 wherein the silicon substrate is formed to include an opening (30) for placement of a active device chip carrier.

Patentansprüche

1. Optische Baugruppe, umfassend:
eine Vielzahl optischer Einrichtungen (34, 36, 40, 44), ein Siliziumsubstrat (11), das definitionsgemäß eine obere Hauptoberfläche (13) umfaßt, wobei das Siliziumsubstrat eine Vielzahl von Öffnungen (12, 20, 22, 30), die in dessen oberer Oberfläche ausgebildet sind, umfaßt, wobei die Vielzahl von Öffnungen für die Anordnung der Vielzahl von optischen Einrichtungen ausgebildet ist und so angeordnet ist, daß optische Ausrichtung zwischen diesen bereitgestellt ist und ein Tragelement (beispielsweise 48, 50), das in Bezug auf das Siliziumsubstrat so angeordnet ist, daß mit diesem eine überkragende Anordnung ausgebildet wird.

2. Optische Baugruppe nach Anspruch 1, ferner umfassend wenigstens eine aktive optische Einrichtung (40).

3. Optische Baugruppe nach Anspruch 2, bei welcher wenigstens eine optische aktive Einrichtung einen Laser umfaßt.

4. Optische Unterbaugruppe nach Anspruch 2, bei welchem die wenigstens eine optische Baugruppe innerhalb einer Öffnung 30 in der oberen Oberfläche des Siliziumsubstrats in Nachbarschaft zum Tragelement angeordnet ist.

5. Optische Baugruppe nach Anspruch 2, bei welcher die Vielzahl von optischen Einrichtungen ferner einen optischen Isolator 44 umfaßt.

6. Optische Baugruppe nach Anspruch 5, bei welcher der optische Isolator eine optische Isolatorkomponente innerhalb einer Öffnung in der oberen Siliziumoberfläche so umfaßt, daß optische Ausrichtung zur aktiven optischen Einrichtung besteht und
einen Permanentmagneten (52), der um die optische Isolatorkomponente so angeordnet ist, daß physikalischer Kontakt zum Siliziumsubstrat vermieden ist.

7. Optische Baugruppe nach Anspruch 2, bei welcher die Vielzahl optischer Einrichtungen ferner wenigstens eine passive optische Komponente (34, 36) umfassen.

8. Optische Baugruppe nach Anspruch 7, bei welcher die wenigstens eine passive optische Komponente eine erste Linse (34) zum Koppeln eines optischen Signals, das aus der optischen Baugruppe austritt, an ein externes optisches Kommunikationsmedium und eine zweite Linse (36), die an die aktive optische Einrichtung zum Kollimieren des optischen Ausgangssignals von dieser gekoppelt ist, umfaßt.

9. Optische Baugruppe nach Anspruch 8, bei welcher das externe optische Kommunikationsmedium eine optische Faser (54) umfaßt.

10. Optische Baugruppe nach Anspruch 8, bei welcher die erste Linse eine Gradientenindexlinse von zylindrischer Form zum Transformieren eines kollimierten Eingangsstrahls in einen fokus-

sierten Ausgangsstrahl umfaßt und die zweite Linse eine sphärische Linse zum Kollimieren des an diese angelegten Eingangssignals umfaßt.

11. Optische Baugruppe nach Anspruch 10, bei welcher das Siliziumsubstrat umfaßt
eine erste Öffnung (18) für die erste Linse, wobei die erste Öffnung eine relativ trapezförmige Form einer Tiefe d_1 aufweist und
eine zweite Öffnung (20) für die zweite Linse, wobei die zweite Öffnung eine relativ quadratische pyramidenförmige Form einer Tiefe d_2 aufweist.

12. Optische Baugruppe nach Anspruch 11, bei welcher die Tiefe d_1 innerhalb des Bereichs von ungefähr 500-700µm liegt und die Tiefe d_2 innerhalb des Bereichs von ungefähr 100-200 µm liegt.

13. Optische Baugruppe nach Anspruch 2, bei welcher das Tragelement einen thermoelektrischen Kühler umfaßt.

14. Optische Baugruppe nach Anspruch 13, bei welcher der thermoelektrische Kühler in Bezug auf das Siliziumsubstrat so angeordnet ist, daß ein thermischer Transportweg durch das Siliziumsubstrat zur aktiven optischen Einrichtung bereitgestellt ist.

15. Optische Baugruppe nach Anspruch 14, bei welcher die Vielzahl von optischen Einrichtungen ferner einen optischen Isolator umfaßt, der eine optische Isolatorkomponente aufweist, die innerhalb einer Öffnung in der oberen Oberfläche des Siliziumsubstrats angeordnet ist und entlang des thermischen Transportweges vom thermoelektrischen Kühler und dem Siliziumsubstrat angeordnet ist.

16. Optische Baugruppe nach Anspruch 2, bei welcher die wenigstens eine aktive optische Einrichtung an einem optischen Trägerchip (38) angeordnet ist, wobei der optische Trägerchip an der oberen Oberfläche des Siliziumsubstrats befestigt ist.

17. Optische Baugruppe nach Anspruch 16, bei welcher der Trägerchip innerhalb einer in der oberen Oberfläche des Siliziumsubstrats ausgebildeten Öffnung befestigt ist, wobei die Tiefe der Öffnung so ist, daß der aktive Bereich der optischen Einrichtung oberhalb der oberen Oberfläche des Siliziumsubstrats angeordnet verbleibt.

18. Optische Baugruppe nach Anspruch 2, bei welcher die wenigstens eine aktive Einrichtung ferner als zweite aktive Einrichtung einen Rückflächenmonitor (46) umfaßt, der angeordnet ist, um das aus der Rückfläche der ersten aktiven optischen Einrichtung austretende optische Signal zu schneiden.

19. Optische Baugruppe nach Anspruch 1, bei welcher das Siliziumsubstrat <100> orientiertes Silizium derart umfaßt, daß die Vielzahl der Öffnungen einwärts geneigte Seitenwände von <111> Orientierung haben.

20. Optische Baugruppe umfassend
eine aktive optische Halbleitereinrichtung (beispielsweise 40), eine Isolationseinrichtung (beispielsweise 44) zum Verhindern, daß reflektierte Signal in die aktive optische Halbleitereinrichtung wieder eintreten,
eine erste Linse (beispielsweise 34), die hinter der Isolationseinrichtung zum Fokussieren des Ausgangssignals von der Isolationseinrichtung in ein gekoppeltes optisches Wellenleitermedium angeordnet ist,
eine zweite Linse (beispielsweise 36), die zwischen der aktiven Einrichtung und der Isolationseinrichtung zum Kollimieren des Ausgangssignals von der aktiven Einrichtung in den Eingang der Isolationseinrichtung angeordnet ist, und
ein Siliziumsubstrat (beispielsweise 11), das eine Vielzahl von Öffnungen umfaßt (beispielsweise 12, 20, 22, 30), die in dessen oberer Oberfläche ausgebildet sind zum Plazieren der Isolationseinrichtung und der ersten und der zweiten Linse, wobei die Vielzahl von Öffnungen so angeordnet ist, daß optische Justierung zwischen diesen bereitgestellt wird.

21. Optische Baugruppe nach Anspruch 20, bei welcher die Isolationseinrichtung umfaßt
eine optische Isolatorkomponente (42), die in einer Öffnung des Siliziumsubstrats angeordnet ist und
einen Permanentmagneten (52), der das Siliziumsubstrat in der Nähe der optischen Isolatorkomponenten umgebend angeordnet ist, wobei die Baugruppe ferner umfaßt
Eine Trageinrichtung (48), die an der Unterseite des Siliziumsubstrats auf eine Weise befestigt ist, daß eine vorkragende optische Baugruppe bereitgestellt wird, bei welcher physikalischer Kontakt zwischen dem Permanentmagneten und dem Siliziumsubstrat vermieden ist.

22. Optische Baugruppe nach Anspruch 21, bei welcher die Trageinrichtung einen thermoelektrischen Kühler umfaßt, der an der Unterseite des Siliziumsubstrats in der Nähe der aktiven optischen Halbleitereinrichtung und der optischen Isolatorkomponente befestigt ist.

23. Optische Baugruppe nach Anspruch 20, bei welcher
die erste Linse eine zylindrische GRIN-Linse (34) umfaßt, die in einer relativ rechteckförmigen pyramidenförmigen Öffnung in dem Siliziumsubstrat angeordnet ist und
die zweite Linse eine sphärische Linse (36) umfaßt, die in einer relativ quadratischen pyramidenförmigen Öffnung in dem Siliziumsubstrat angeordnet ist.

24. Optische Baugruppe nach Anspruch 20, bei welcher das Siliziumsubstrat mit einer Öffnung (30) für das Anordnen eines Chipträgers einer aktiven Einrichtung ausgebildet ist.

Revendications

1. Un sous-ensemble optique comprenant :
un ensemble de dispositifs optiques (34, 36, 40, 44) ;
un substrat en silicium (11) défini de façon à comprendre une surface supérieure principale (13), ce substrat en silicium comprenant un ensemble d'ouvertures (12, 20, 22, 30) formées dans sa surface supérieure, l'ensemble d'ouvertures étant prévues pour le placement de l'ensemble de dispositifs optiques et étant disposées de façon à établir un alignement optique entre eux ; et
un élément de support (par exemple 48, 50), disposé par rapport au substrat en silicium de façon à former une configuration en porte-à-faux avec ce dernier.

2. Un sous-ensemble optique défini dans la revendication 1, comprenant en outre au moins un dispositif optique actif (40).

3. Un sous-ensemble optique défini dans la revendication 2, dans lequel le ou les dispositifs optiques actifs comprennent un laser.

4. Un sous-ensemble optique défini dans la revendication 2, dans lequel le dispositif optique actif, ou chacun d'eux, est placé à l'intérieur d'une ouverture (30) dans la surface supérieure du substrat en silicium, à proximité de l'élément de support.

5. Un sous-ensemble optique défini dans la revendication 2, dans lequel l'ensemble de dispositifs optiques comprend en outre un isolateur optique (44).

6. Un sous-ensemble optique défini dans la revendication 5, dans lequel l'isolateur optique comprend
un composant optique d'isolateur placé à l'intérieur d'une ouverture dans la surface supérieure du substrat en silicium, de façon à être en alignement optique avec le dispositif optique actif ; et
un aimant permanent (52) disposé de façon à entourer le composant optique d'isolateur de manière à éviter un contact physique avec le substrat en silicium.

7. Un sous-ensemble optique défini dans la revendication 2, dans lequel l'ensemble de dispositifs optiques comprend en outre au moins un composant optique passif (34, 36).

8. Un sous-ensemble optique défini dans la revendication 7, dans lequel le ou les composants optiques passifs comprennent
une première lentille (34) pour coupler vers un milieu de communication optique externe un signal optique qui sort du sous-ensemble optique ; et
une seconde lentille (36) couplée au dispositif optique actif pour collimater l'émission optique de ce dernier.

9. Un sous-ensemble optique défini dans la revendication 8, dans lequel le milieu de communication optique externe comprend une fibre optique (54).

10. Un sous-ensemble optique défini dans la revendication 8, dans lequel
la première lentille consiste en une lentille à gradient d'indice de forme cylindrique, pour transformer un faisceau d'entrée collimaté en un faisceau de sortie focalisé ; et
la seconde lentille consiste en une lentille sphérique pour collimater le signal d'entrée optique qui lui est appliqué.

11. Un sous-ensemble optique défini dans la revendication 10, dans lequel le substrat en silicium comprend
une première ouverture (18) pour la première lentille, cette première ouverture ayant une forme relativement trapézordale d'une profondeur d_1 ; et
une seconde ouverture (20) pour la seconde lentille, cette seconde ouverture ayant une forme relativement pyramidale carrée d'une profondeur d_2.

12. Un sous-ensemble optique défini dans la revendication 11, dans lequel la profondeur d_1 est dans la plage d'environ 500-700 μm, et la profondeur d_2 est dans la plage d'environ 100-200 μm.

13. Un sous-ensemble optique défini dans la revendication 2, dans lequel l'élément de support comprend un dispositif de refroidissement thermo-électrique.

14. Un sous-ensemble optique défini dans la revendication 13, dans lequel le dispositif de refroidissement thermoélectrique est disposé par rapport au substrat en silicium de façon à établir un chemin de transfert thermique à travers le substrat en silicium, vers le dispositif actif.

15. Un sous-ensemble optique défini dans la revendication 14, dans lequel l'ensemble de dispositifs optiques comprend en outre un isolateur optique comprenant un composant optique d'isolateur qui est placé à l'intérieur d'une ouverture dans la surface supérieure du substrat en silicium, et qui est disposé le long du chemin de transfert thermique entre le dispositif de refroidissement thermoélectrique et le substrat en silicium.

16. Un sous-ensemble optique défini dans la revendication 2, dans lequel le dispositif optique actif, ou chacun d'eux, est disposé sur un support de puce optique (38), ce support de puce optique étant fixé sur la surface supérieure du substrat en silicium.

17. Un sous-ensemble optique défini dans la revendication 16, dans lequel le support de puce est fixé à l'intérieur d'une ouverture formée dans la surface supérieure du substrat en silicium, la profondeur de l'ouverture étant telle que la région active du dispositif optique reste placée au-dessus de la surface supérieure du substrat en silicium.

18. Un sous-ensemble optique défini dans la revendication 2, dans lequel les dispositifs actifs comprennent en outre à titre de second dispositif actif, un dispositif de contrôle de face arrière (46) qui est positionné de façon à intercepter le signal optique sortant par la face arrière du premier dispositif actif.

19. Un sous-ensemble optique défini dans la revendication 1, dans lequel le substrat en silicium consiste en silicium d'orientation <100> , de façon que l'ensemble d'ouvertures comprennent des parois latérales allant en se rapprochant vers l'intérieur, d'orientation <111>.

20. Un sous-ensemble optique comprenant

un dispositif optique à semiconducteurs actif (par exemple 40) ;

des moyens d'isolation (par exemple 44), pour empêcher que des signaux réfléchis ne retournent vers l'intérieur du dispositif optique à semiconducteurs actif ;

une première lentille (par exemple 34), disposée après les moyens d'isolation, pour focaliser l'émission de sortie des moyens d'isolation vers un milieu de guidage d'ondes optique couplé ;

une seconde lentille (par exemple 36), disposée entre le dispositif actif et les moyens d'isolation, pour collimater l'émission du dispositif actif vers l'entrée des moyens d'isolation ; et

un substrat en silicium (par exemple 11) comprenant un ensemble d'ouvertures (par exemple 12, 20, 22, 30) formées dans sa surface supérieure, pour le placement des moyens d'isolation et des première et seconde lentilles, l'ensemble d'ouvertures étant disposées de façon à assurer un alignement optique entre eux.

21. Un sous-ensemble optique défini dans la revendication 20, dans lequel les moyens d'isolation comprennent

un composant optique d'isolateur (42) placé dans une ouverture dans le substrat en silicium ; et

un aimant permanent (52) disposé de façon à entourer le substrat en silicium au voisinage des composants optiques d'isolateur ;

le sous-ensemble comprenant en outre

des moyens de support (48) fixés sur la face inférieure du substrat en silicium, de manière à procurer une configuration de sous-ensemble optique en porte-à-faux, dans laquelle un contact physique entre l'aimant permanent et le substrat en silicium est évité.

22. Un sous-ensemble optique défini dans la revendication 21, dans lequel les moyens de support comprennent un dispositif de refroidissement thermoélectrique qui est fixé à la face inférieure du substrat en silicium, au voisinage du dispositif optique à semiconducteurs actif et du composant optique d'isolateur.

23. Un sous-ensemble optique défini dans la revendication 20, dans lequel

la première lentille consiste en une lentille GRIN cylindrique (34), placée dans une ouverture relativement pyramidale rectangulaire dans le substrat en silicium ; et

la seconde lentille consiste en une lentille sphérique (36), placée dans une ouverture relativement pyramidale carrée dans le substrat en silicium.

24. Un sous-ensemble optique défini dans la revendication 20, dans lequel le substrat en silicium est formé de façon à comprendre une ouverture (30) pour le placement d'un support de puce de dispositif actif.

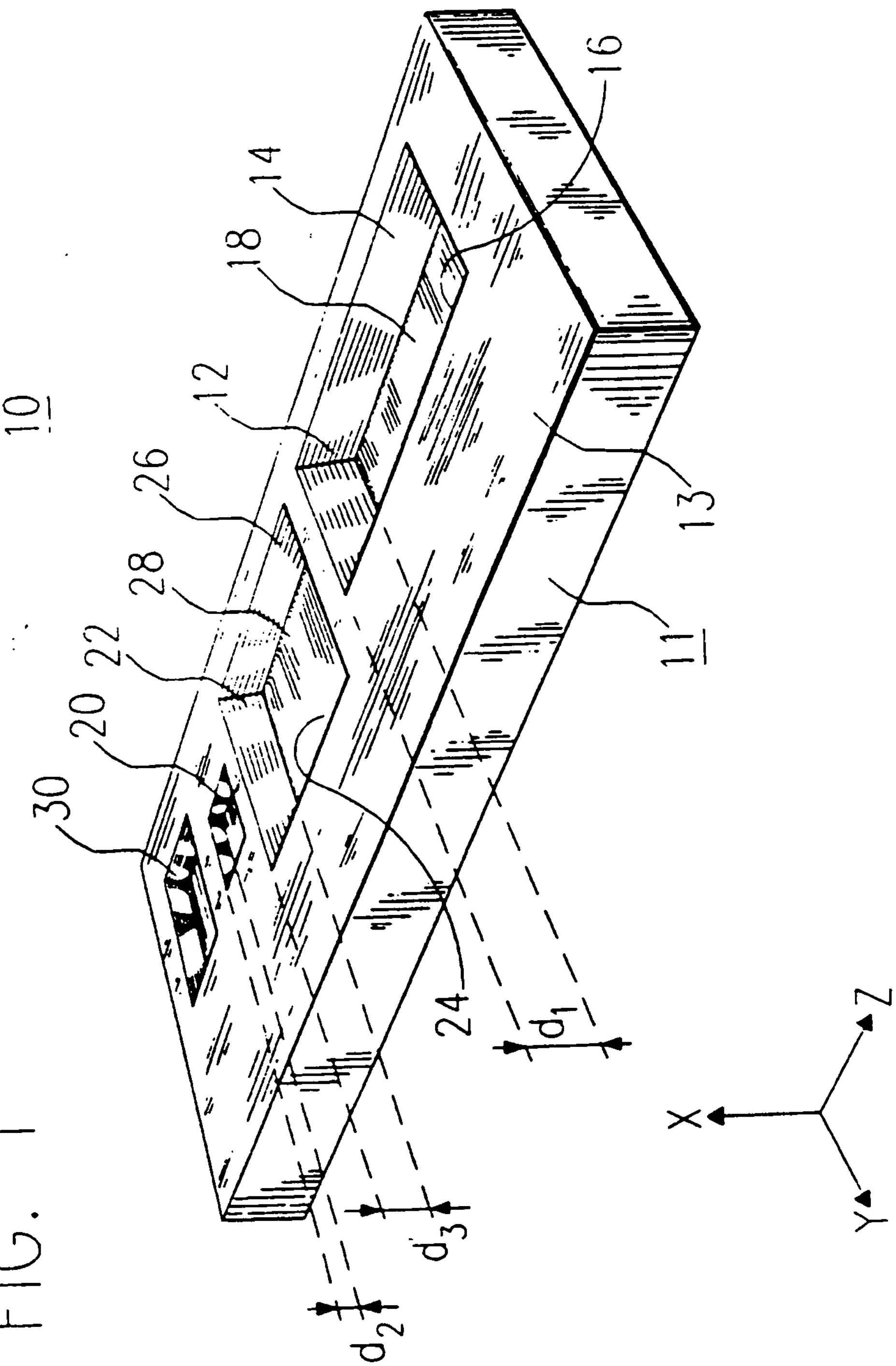


FIG. 1

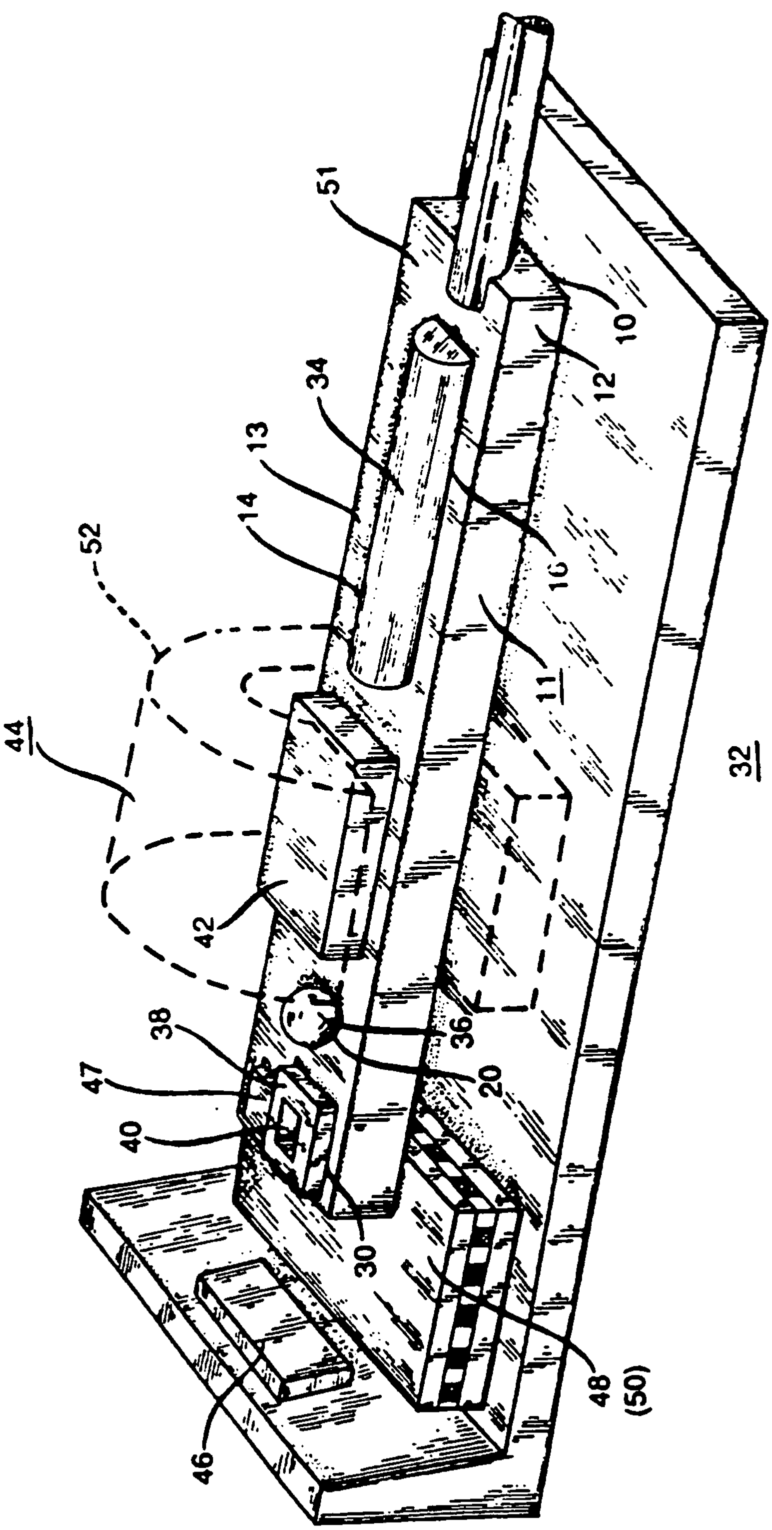


FIG. 2

FIG. 3

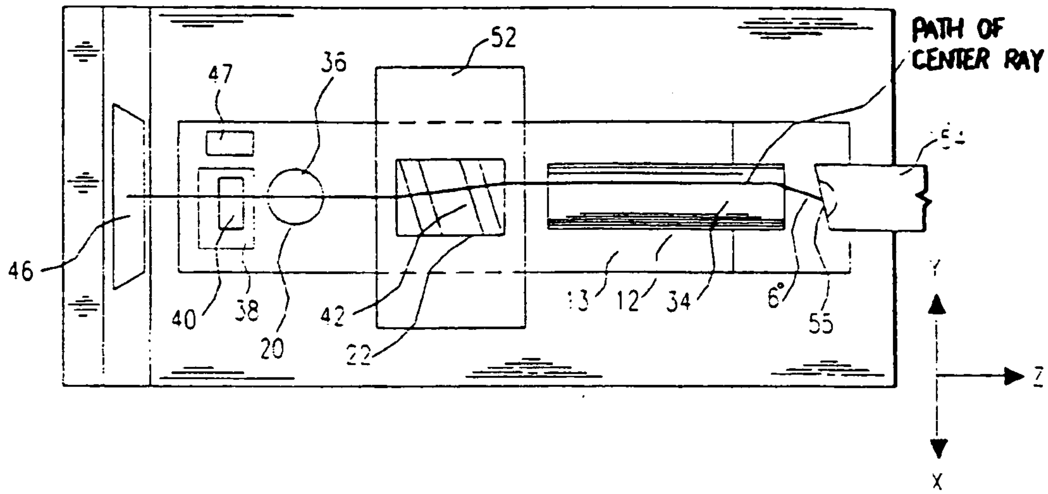

PATH OF CENTER RAY
52
47
36
54
46
40
38
20
42
22
13
12
34
6°
55
Y
Z
X

FIG. 4

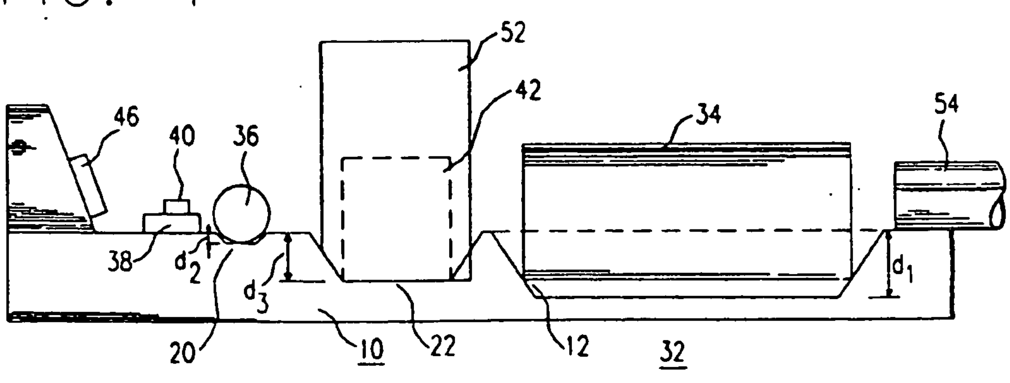

52
42
46
40
36
34
54
38
d_2
d_3
d_1
20
10
22
12
32

FIG. 5

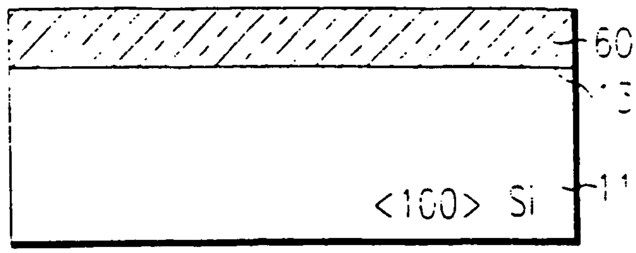


FIG. 6

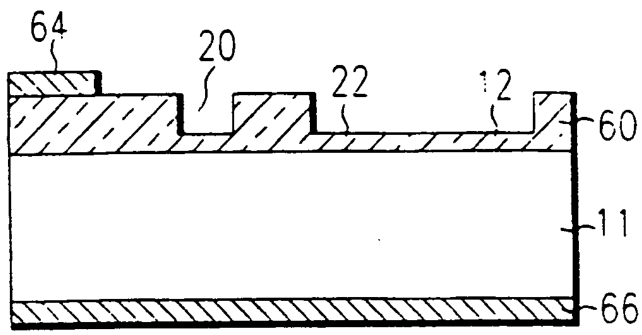


FIG. 7

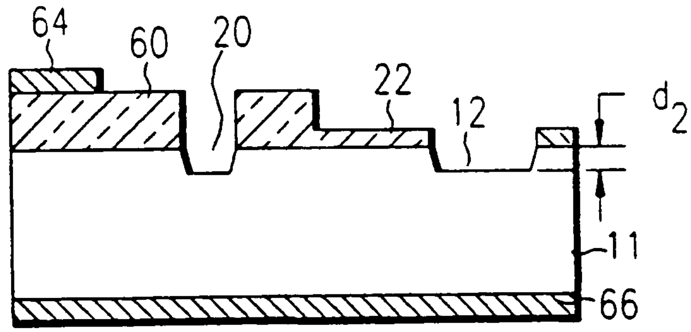
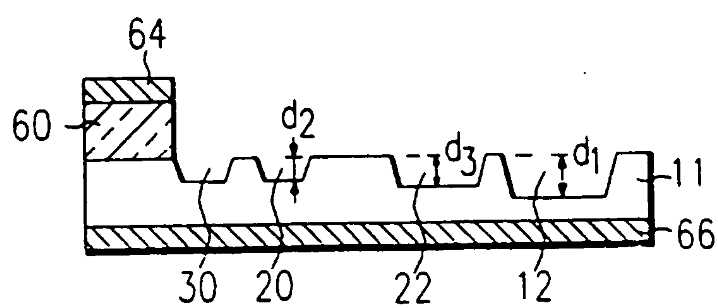


FIG. 8



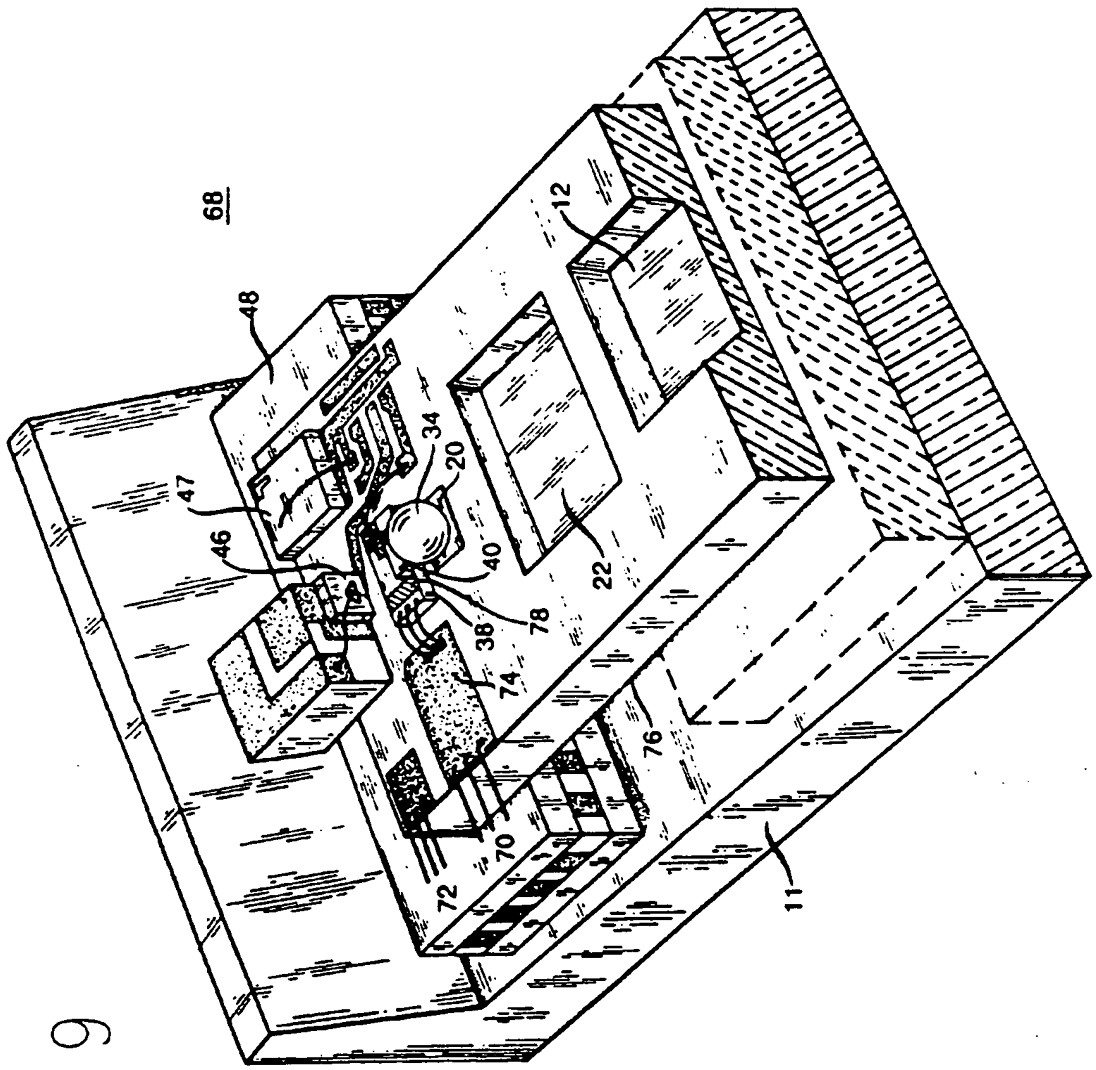


FIG. 9